California Tests Show Pavement Selection Influences Noise Levels

By Bruce Rymer, Division of Environmental Analysis, California Department of Transportation (Caltrans); and Paul Donavan, Illingworth & Rodkin, Inc.

James Reyff performs continuous wayside sound measurements at I-80 outside of Davis, Calif.

Traffic noise has become a growing public concern and the California Department of Transportation (Caltrans) has responded by initiating a number of studies to examine the impact various standard pavements have on traffic noise levels.

The European community has been experimenting with quiet pavements for many years, and in May 2004, the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) jointly sponsored an international scanning tour to examine European quiet pavement technology.

In September 2004, Caltrans, General Motors, and the FHWA sponsored a follow-up study that used the sound intensity technology to measure and compare some of the European quiet pavements seen on the scanning tour to the California and Arizona quiet pavements.

The Noise Intensity Testing in Europe (NITE) study is the first definitive comparison of quiet pavements on multiple continents. Among the many findings of the NITE study, the principle conclusion is that several of the quietest 'off-the shelf' open-graded asphalt pavements in California and Arizona compare very favorably to the optimized quiet pavements of Europe.

Introduction

Within the United States, the primary method for mitigating traffic noise is the construction of sound walls to intercept the transmission between the traffic noise source and the receiver. Sound walls have geometric limitations; they have to interrupt the line-of-sight between the source and the receiver and they effectively attenuate noise levels only 200 to 250 feet directly behind the wall. The State of California constructs sound walls only when a "readily noticeable" reduction of 5 dBA can be achieved. At more than $1.3 million per mile, sound walls are the only noise mitigation solution recognized by the Federal Highway Administration (FHWA).

The shortcomings of sound walls become especially apparent when the walls block scenic views, negatively impact future road widening projects, add additional dead weight to bridge structures, or simply fail to effectively shield receivers from traffic noise. For these reasons, several years ago, Caltrans became interested in the use of "quiet pavements" as an alternative approach to turning down the volume of the irritating noise at the source rather than try to intercept, interrupt, or contain the objectionable sound.

One of the concerns about asphalt-based quiet pavements has been its longevity in abating traffic noise. To develop an understanding of this issue, Caltrans has embarked on several projects investigating the long-term performance of potentially quiet, thin lift asphalt overlays. The first of these was on a portion of the heavily trafficked I-80 near Davis, Calif. This project is in its seventh year of investigation. Caltrans also used a new measurement technique, On-Board-Sound-Intensity (OBSI), for measuring and comparing and indexing pavement acoustics.

Database of pavement noise performance

Since its inception, Caltrans' pavement noise index or database has grown to over 100 different pavements and bridge decks and includes data from both California and Arizona. The difference, including extremes, between the quietest and loudest pavements can span as much as 16 dBs. Within this data set, generic pavement groupings include "PCC" for Portland Cement Concrete, "DGA" or "DGAC" for Dense Graded Asphalt Concrete, and "OG/RAC" for Open Graded/Rubber Asphalt Concrete.

The quietest or lower one-third of all the pavements are either open-graded and/or rubberized asphalt. The middle one-third are mostly dense-graded asphalt with some overlap of OGAC and quieter textured PCC surfaces. The upper one-third or loudest pavements tend to be aggressively textured PCC and large angular aggregate ACs that generated high levels of lower frequency noise.

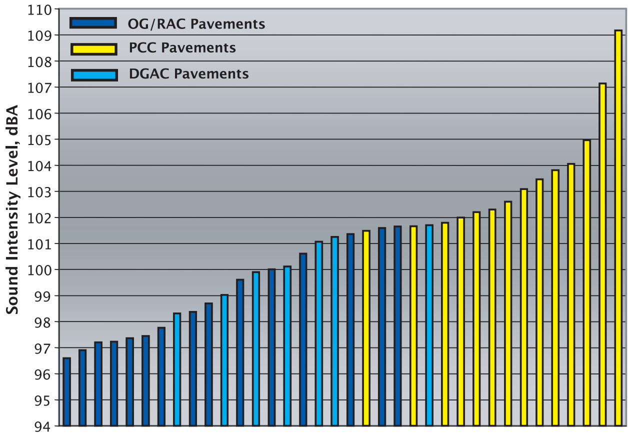


Figure 1: Range of tire/pavement noise levels from California and Arizona roadways.

I-80 Davis OGAC long-term study

In 1998, Caltrans began a long-term study of the effect of an OGAC pavement overlay applied to a 9-kilometer stretch of I-80 just east of Davis, Calif. Prior to the pavement rehabilitation project, the roadway bed consisted of 120 to 160 mm of aged DGAC. In some spots, the underlying base was removed and replaced. The new AC surfacing began with the placement of 60 mm of DGAC as a leveling course in June and early July 1998. This was subsequently covered with 25 mm of OGAC in July 1998. Since that time, the noise performance of the overlay has been monitored using time-averaged wayside measurements made in late fall/early winter, spring, and June of each year.

Los Angeles County 138 test site

In 2002, Caltrans constructed five sections of different types of AC pavement on a portion of State Route 138 in a remote area in northern Los Angeles County. These sections consisted of a dense graded asphalt concrete which was to serve as a reference section over time, an open-graded asphalt concrete 75 mm in thickness, another OGAC section 30 mm in thickness, an open-graded rubberized asphalt concrete surface (RAC(O)), and a bonded wearing course (BWC) surface. In the initial measurements, all test sections displayed lower levels than the reference DGAC for both passby measurements of the controlled test car and sound intensity. The thicker OGAC pavement is consistently quieter. However, the RAC(O) surface is almost as quiet as the OGAC. The thinner OGAC is slightly noisier than these two surfaces. These results were confirmed by independent statistical-pass-by measurements completed by the US DOT Volpe Center.

continued on page 30

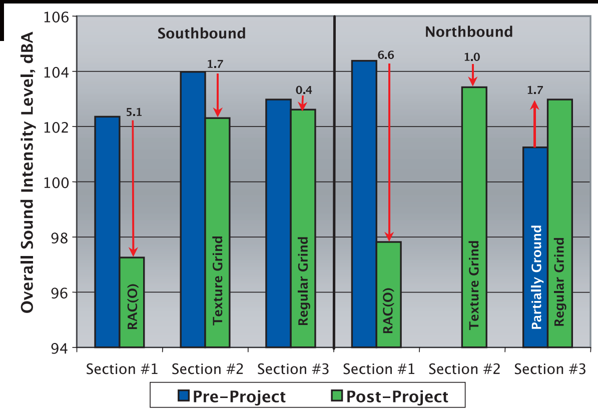


Figure 2: Pre- and post-project overall sound intensity levels for I-280 pavement rehabilitation with the indicated reduction for each section.

Between June and November of 2002, Caltrans completed a pavement rehabilitation project on a portion of Interstate 280 in San Mateo County, California. The existing pavement was older PCC with some slab faulting. The faulting was repaired as required and new surface treatments applied. All of the PCC lanes were ground using a "regular" diamond grinding process. Additional sections received an open graded, rubberized asphalt concrete RAC(O) overlay. As a result, in the post-project state, three new surfaces existed on this segment of I-280 in both the north and south bound directions. In order to capture the change in pavement/tire noise with these new surfaces, pre- and post-project SI measurements were conducted.

This data indicate several things. First, in all cases where direct comparison is available, all of the surfaces produced improvement. The reductions with the RAC(O) were greater than either of the grindings applied to the PCC. One interesting aspect of the pre-project data is the 2 dB range in level.

For this project, the data indicated that the RAC(O) produced a project average of 6.2 dB reduction, the regular grind, a 1.0 dB reduction, and the texture grind, a 0.9 dB reduction. One interesting side note to this testing was that the highway shoulders were non-rubber OGAC. Direct comparison between the OGAC shoulder and the RAC(O) travel lane yielded virtually the same acoustic results.

Noise Intensity Testing in Europe

With the development of a consistent tire/pavement noise data base in California and Arizona, there was considerable interest in applying the OBSI measurement approach to pavements in Europe. In May of 2004, a delegation from the U.S. undertook a "scan" tour of European countries to discover and document the state of the practice in European technology for quiet pavement systems. The Europeans have been experimenting with quiet pavement design much longer than the U.S. Although this tour was successful in its qualitative assessment, because of measurement method and test tire differences between researchers in Europe and the U.S., there was no common scale to compare the performance of European pavements to those in the U.S. To fill this void, Caltrans initiated a project to perform OBSI measurements in Europe that could be compared directly to those in the California/Arizona (CA/AZ) database. This became the Noise Intensity Testing in Europe or "NITE" Project. General Motors supplied logistical support and the FHWA made a financial contribution to the project.

Project definition

In principle, sound intensity measurements of European roadways could readily be accomplished, as the sound intensity fixture and measurement equipment are quite portable. After the verification testing at the General Motors Opel Proving Ground, sound intensity measurements were conducted in four different countries on a total of 66 different pavements. As the primary interest of the project was for higher speed pavement performance, the majority of the testing was performed at 97 km/h. However, 33 pavements were also tested at 56 km/h. The test pavements were located in Germany, the Netherlands, France, and Belgium. The measurement period was three weeks in duration and was completed in October of 2004.

Results of testing

The abbreviations are "PA" for Porous Asphalt, "DLPA" for Double Layer Porous Asphalt, and "SMA" for Stone Matrix Asphalt. In CA/AZ, the term "open graded" is somewhat casually used to refer to AC surfaces that may have some degree of porosity. However, these can have lower void ratios, on the order of 5 to 8 percent. In Europe, porous pavements typically imply void ratios on the order of 15 to 20 percent. To distinguish this, the "PA" nomenclature is used in Figure 12. The DLPA nomenclature refers to two layers of porous AC typically

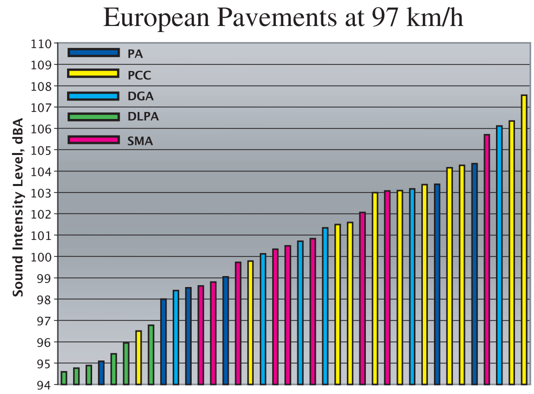


Figure 3: Range of overall A-weighted sound intensity levels at 97 km/h as measured in Europe for the NITE project.

with differing aggregate size ranges to achieve different amounts of permeability.

Typically, the top layer is constructed of smaller aggregate to reduce noise while the lower layer uses larger aggregate to improve drainage. Different top layer aggregate sizes are used to optimize noise performance. SMA pavements are not common in California. These pavements typically feature a large amount of stone-to-stone contact, viscous binder, and low air voids. It should be noted that in Europe, pavements termed dense-graded AC appeared to be quite different than those in California.

The overall ranges in noise levels for typical CA/AZ pavements and European pavements are nearly identical at about 13 dB. In terms of absolute level, the quietest European pavements are slightly lower (~2 dB) than the quietest from the CA/AZ database.

The exception to this is the DLPA category, which, as a group, defined the quieter end of the data set. It is also noteworthy that one of the PCC pavements produced levels comparable to the DLPA surfaces. This was a porous PCC pavement with a diamond-ground surface.

The levels for the quietest and loudest pavements in both data sets are virtually identical. Similarly, at 97 km/h, the ground porous PCC pavement was almost as quiet as the quietest AC pavements. A second, unground porous PCC, is also included in this data set (not in the 97 km/h data set), and it also performed well being only about 1 dB higher than the ground section.

Although the rank ordering is not perfect, the general trend is that the smaller aggregate sizes produce lower noise levels. This trend is not unexpected based on other pavement noise studies.

It has also reported that porous AC surfaces can loose their porosity through clogging over time, which may account for a portion of the range of noise performance indicated. In contrast to the single layer PA, the double layer PA surfaces display remarkably little range in SI levels, and all surfaces performed relatively well. The consistency of these results may be due to the fact that all these surfaces were relatively new or were on test tracks instead of in-use roadways.

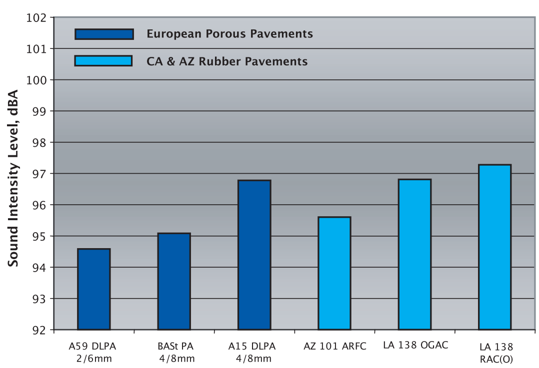
Comparisons between the NITE and CA/AZ results

One of the main purposes of the NITE project was to determine if the pavement technology in Europe produced quieter pavements. As the lowest levels were measured in the Netherlands, these data were chosen for these comparisons. The typical improvement in level with the DLPA is about 10 dB. In Arizona, although there is a limited amount of longitudinal and random transverse tined PCC, the bulk of the PCC is uniform transverse tined. Relative to Arizona, Asphalt Rubber Friction Courses (ARFC) overlays that have been recently applied in the Arizona Quiet Pavement Pilot Project, reductions on the order of 9 dB are typical. In California, however, the range of possible improvement is smaller primarily due to the absence of the use of transverse tining on grade PCC surfaces. As a result, the typical higher levels are about 3 dB lower than Arizona or the Netherlands and the range of possible improvement is on the order of 6 dB.

It is also instructive to compare the quieter pavements measured in Europe, California, and Arizona. In Europe, the quieter pavements are “drainage” pavements, intentionally constructed to be water (and air) permeable. As a result, they should provide sound absorption characteristics, which would decrease tire noise generation and propagation. For the CA/AZ surfaces, high permeability is not necessarily achieved with the open-graded designs.

Further, there has been no indication of improved sound absorption of these surfaces relative to others. However, two of three CA/AZ pavements contain rubber, which is not found in European pavements. At this time, the role of the rubber content on noise performance is not understood.

Another difference is that European porous pavements tend to be thicker, by 40 to 120 mm. For the CA/AZ rubberized pavements (AZ ARFC & LA 138 RAC(O)), the overlays are thinner (25 to 30 mm total thickness), but can achieve virtually the same acoustical performance of the thicker permeable European surfaces. A final difference between the European pavements and the CA/AZ pavements is aggregate size. The European pavements have maximum aggregate sizes of 6 to 8 mm. The CA/AZ pavements range from 9.5 mm to 12.5 mm. The relationships between permeability, porosity, pavement thickness, aggregate size, and rubber content are clearly an area for further work.



Summary

From the Caltrans studies performed in California and Arizona, the following observations have been made:

- As a group, open-graded and/or rubberized asphalt concrete show the best tire/pavement noise performance.
- Grinding of PCC surfaces can be effective in reducing tire/pavement noise by reducing texture effect (such as transverse tining) and by reducing joint slap.

From the NITE testing, the following observation was made:

- Highly porous two-layer AC constructions can provide only slightly better tire/pavement noise performance than the quiet pavements currently in use in California and Arizona. HMAT

For a complete report, including additional charts, photographs, and information, contact Caltrans and request the report entitled: "Tire/Pavement Noise Intensity Testing in Europe."